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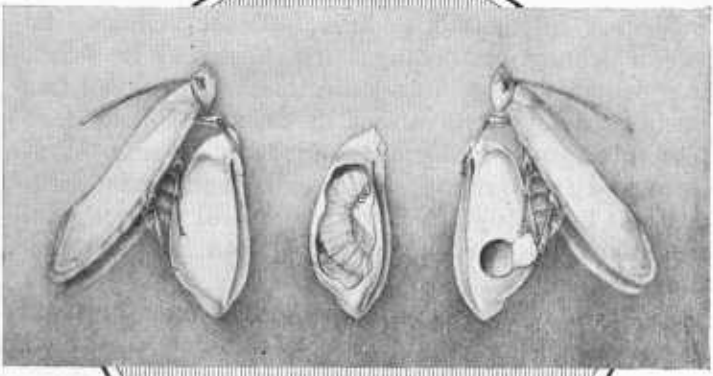
ANGOUMOIS GRAIN MOTH



THE ANGOUMOIS grain moth, primarily a pest of wheat and corn in this country, attacks all cereal grains. It is particularly injurious throughout the Southern States. It does little harm north of central New Jersey except to cereals in storage.

It is second to the rice or "black" weevil in its capacity to damage grain. Often entire crops of corn and wheat are ruined. Millers are known to have refused to buy badly affected crops, as flour made from damaged wheat is not fit to eat. Wheat loses through moth attack about 52 per cent in weight. Corn, being larger, loses from 12 to 24 per cent in weight when kernels are attacked by a single insect only. As many as three or four moths, however, may develop in one corn kernel. The feeding of a single insect will completely ruin so small a grain as milo or sorghum.

Farmers suffer losses unnecessarily, for losses can be prevented by watchfulness and by application of measures advocated in this bulletin. Choose between prompt harvesting, early threshing or shucking, proper storage, and little loss, and delayed harvesting, delayed threshing in case of wheat, careless or improper storage, and large losses. Well-informed farmers are storing corn and wheat without loss by giving attention to cultural methods and treatment in storage by fumigation. Where one succeeds, all can.

All farmers can support campaigns to kill out the Angoumois grain moth. No pest can be controlled more effectively. If county agents will unite farmers to fight this pest they will save their counties grain worth many times the salaries paid them. Success awaits intelligent action.

Washington, D. C.

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ANGOUMOIS GRAIN MOTH[1]

By E. A. BACK, *Principal Entomologist in Charge, Division of Stored-Product Insects, Bureau of Entomology*

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ESTABLISHMENT AND SPREAD IN AMERICA

THE ANGOUMOIS GRAIN MOTH is a European pest that has become destructive to corn, wheat, and other grains in this country as a result of international commerce. It is called the Angoumois grain moth because as early as 1736 it had been a pest in the Angoumois Province of France, which included a region near the west coast north of Bordeaux. It is known also in America by the popular name of "fly weevil."

In the early days of American history there were no quarantine regulations to protect our agriculture from foreign pests. The Angoumois grain moth is one of those pests that are easily carried in grain from place to place. It was brought many times to this country in seed introduced from Europe by the earlier settlers of the various colonies along the Atlantic seaboard. Since it is a pest that is easily killed out by very cold winters, it is natural that its establishment in this country occurred in one of the Southern States. The first report of the occurrence of the Angoumois grain moth in this country was in 1728 in North Carolina, where it was causing damage to wheat. It was first reported in Maryland about 1769. Between 1728 and 1775 it had spread northward into Virginia, Maryland, lower Delaware, and probably southern New Jersey. In 1852 Harris wrote that wheat in Kentucky and in the southern parts of Ohio and Indiana was already affected. Though exact records of spread are not available, it is enough to know that from the original North Carolina-Virginia infestation the Angoumois grain moth has spread, chiefly through the shipment of seeds, southward through all the Southern States and northward. The farther south it has spread the more destructive it has become, because it can multiply unhampered by long, cold winters. On the other hand,

[1] *Sitotroga cerealella* Oliv.

its spread northward has been limited by increasingly cold winter weather.

While the moth causes much injury to the wheat crops in the southern parts of the North Central States and New Jersey, Delaware, southeastern Pennsylvania, Maryland, Virginia, and southward, crops grown still farther north are increasingly immune to attack in the field. After one passes the fortieth degree of north latitude injury from the Angoumois grain moth decreases rapidly. Because of the ease with which it can be carried in seeds the Angoumois grain moth is now and then reported from all States, even those possessing a climate far too cold to permit it to become a general pest.

DESCRIPTION

The Angoumois grain moth passes through the usual insect stages—the parent insect or moth, the egg, the larva, and the pupa.

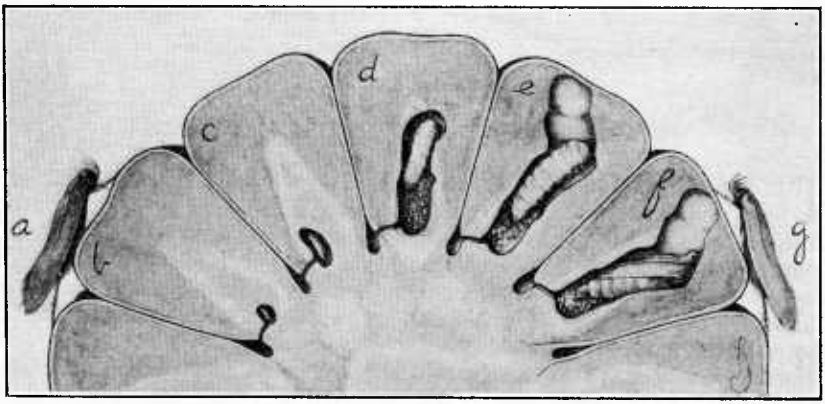

FIGURE 1.—Life cycle of the Angoumois grain moth in corn. The adult moth is shown at *a* and *g*. The larva is shown in different stages of its growth at *b*, *c*, *d*, and *e*. Notice that it begins feeding at the soft germ end of the seed and as it becomes larger eats out into the harder part of the corn. The larva transforms to the pupa as shown at *f*. From the pupa develops the adult moth *g* of the second generation

The moth is shown in Figures 1, 8, 11, and on the title page. It varies somewhat in color from buff to grayish or yellowish brown. In size it varies with the size of the grain in which it matures, but is never more than 0.6 to 0.7 of an inch from tip to tip of wings when these are spread as shown in Figure 8. The average wing spread of the moth is about one-half inch. Whenever moths of this size, closely resembling ordinary clothes moths, are seen flying about grain it is reasonably certain that the grain is infested with the Angoumois grain moth. The eggs laid by the moth are about one-fortieth of an inch long and are too small to be seen without the aid of a magnifying glass. They are laid on or near the grain. They are white when first deposited, but later turn a reddish color before the larva or grub hatches. An egg is shown in Figure 8, *b*. The larva is shown in Figures 1 and 8, and on the title page. When just hatched, the larva is tiny, being no thicker than a hair. After feeding in the grain it becomes full grown and is then about one-fifth of an inch long,

white, with a yellowish-brown head. The pupa or chrysalis is reddish brown and is shown in Figures 1, 5, and 8.

INJURY

Injury to grains by the Angoumois grain moth is always done by the larvae. Injury is more difficult to detect in the early stages of infestation because the grub or larva bores its way into the seed when it is so small that the hole by which it enters can not be found without a close search with a magnifying glass. Usually after it has eaten its way into the seed, the larva turns about and spins a silken web over the opening by which it entered, thus making it even more difficult to locate the entrance hole. Once within the seed, the grub eats out the interior where it feeds unseen and often unsuspected by the owner of the grain. Usually the first indication the average grower has that his grain is infested is the simultaneous appearance of moths and the round holes (figs. 2, 5, 7, 8, and 9) that appear in the individual kernels, or sometimes by the heating of the grain in the bin. Then he finds upon cutting open the seeds in which the holes have appeared that they have been hollowed out by the larva (figs. 1, 4, 5, and 8) and that his grain has not only lost heavily in weight but that it contains much excrement and webbing left behind by the insect. The larva has jaws called mandibles, and it uses them almost continuously, first to gnaw its way into the seed and then to eat out the contents of the seeds to secure nourishment for its growth and to make the circular opening through which the moth itself emerges from the seed. The circular opening is not cut until the larva has become full grown. It then eats out a channel to the outside of the seed, leaving the merest film of the seed coat intact. The moth is strong enough to push off this "cap" when it leaves the seed. The opening is often called the emergence hole.

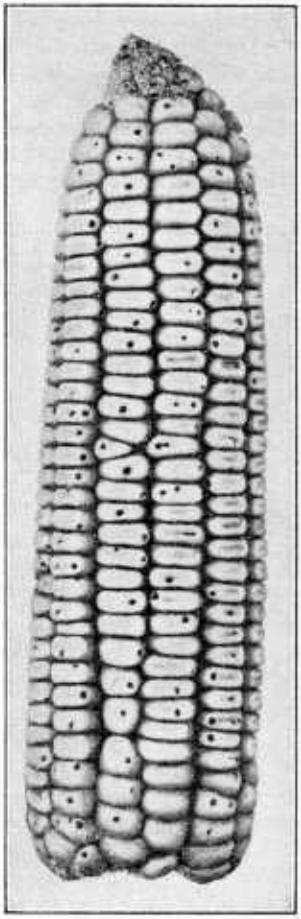

FIGURE 2.—An ear of corn showing the emergence holes of the Angoumois grain moth. When these holes begin to appear in your corn and small clothes-mothlike millers are found flying when the corn is disturbed, you may be certain that the Angoumois grain moth is already damaging your corn

FACTS REGARDING LIFE HISTORY

Under ordinary climatic conditions in those parts of the United States where the Angoumois grain moth is a pest, temperature seems the most important controlling factor in development. All the insects are killed if the infested grain is subjected to 120° F. for several hours. Exposure to 1° for 24 hours has prevented eggs from hatch-

ing. Ordinary winter storage below 60° will hold the moth in a quiescent or dormant state, provided the grain is not so badly infested that it is heating. Development goes on slowly between 60° and 70° and very rapidly between 70° and 95°. This explains how the Angoumois grain moth can breed generation after generation in warehouses or rooms kept at a moderately high temperature in a cold climate where the outdoor temperatures are too low for the moth.

During the summer and early fall the moths mate as soon as they crawl from the seeds in which they have developed. The female may start laying her eggs in less than 24 hours after emergence. Recent studies indicate that the moths are more prolific than was once believed.[2] Moths may lay as many as 300 eggs (283 eggs is the largest number actually laid by any one female under observation) although 150 is probably a fair average. The eggs are deposited singly or in batches on or near the grain. One female that began laying in late August deposited 204 eggs, as follows: 110, 33, 24, 16, 11, and 10 eggs, respectively, on the first, second, third, fourth, fifth, and sixth days. Another female, which emerged early in October, deposited 263 eggs during the 20 days after emergence. Naturally there exists considerable variation in the egg-laying capacity. Usually mated adults live about two weeks, but they may live as long as 38 days. As the males seem to emerge more quickly than the females, and as the sexes are about equally divided, the opportunity for mating and the production of fertile eggs is excellent. Though female moths may develop and lay eggs when they have nothing upon which to feed, access to water in the form of dew on growing wheat and corn appears to increase their egg-laying capacity.

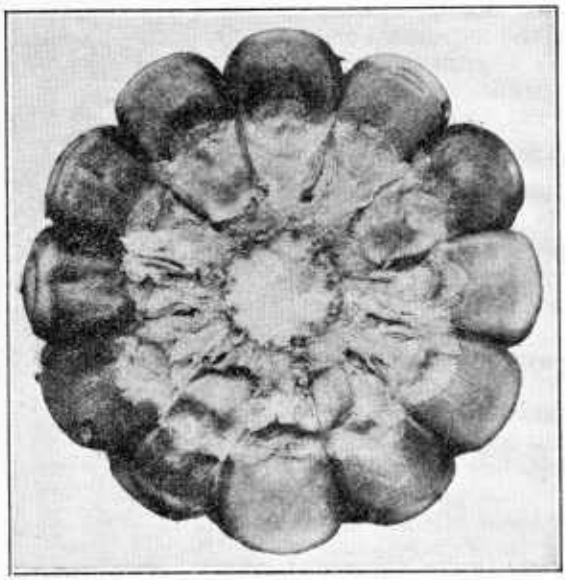

FIGURE 3.—An ear of corn badly damaged by the Angoumois grain moth, broken in two to show how perfect the kernels may appear when viewed from the side

During summer weather the eggs hatch when from 4 to 10 days old. Eggs may not hatch in colder weather for three or four weeks. In new-crop wheat the insects may require only 28 days from the hatching of the egg to the emergence of the moth from the kernel. This makes possible a minimum life cycle of a little less than five weeks.

[2] SIMMONS, P., and ELLINGTON, G. W. BIOLOGY OF THE ANGOUMOIS GRAIN MOTH. PROGRESS REPORT. Jour. Econ. Ent., Vol. 17, pp. 41–45, 1924.

But there may be a variation as wide as four weeks in the time it requires specimens of the same brood to mature even in warm weather. Individuals hatching late in the season overwinter as larvae in the seeds. During the cold winter months the larvae lie dormant for four or five months, hence the life cycle may be fully six months long when a winter intervenes between the laying of the eggs and the emergence of the adults.

In the southern wheat belt of New Jersey there may be five generations of moths in a year under prevailing cultural conditions when wheat is left in the field until late in the season. The farther south one goes the greater is the number of generations, and in heated warehouses or rooms there may be as many as 10 or 12 generations per year.

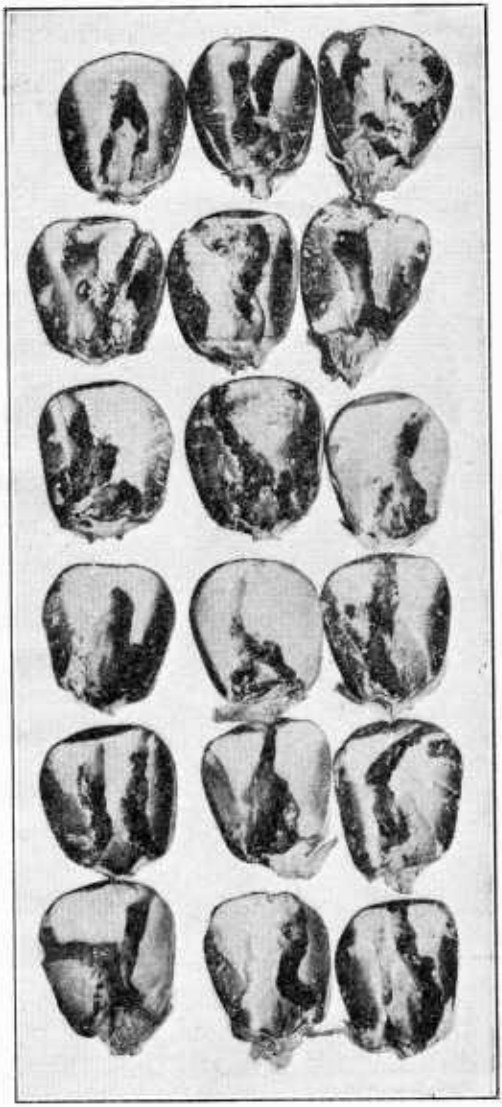

FIGURE 4.—Kernels of corn cut in two to show the damage caused by the larva or worm of the Angoumois grain moth. The worm usually enters the seed at the base, destroys the germ, and then tunnels toward the tip of the kernel. Affected kernels nearly always are ruined for planting purposes

ALL CEREAL GRAINS AFFECTED

The Angoumois grain moth has been bred from wheat, barley, oats, buckwheat, corn, sorghum, milo, rice, beans, chickpeas, and cowpeas. It is a general feeder upon seeds of the cereal type. It causes greatest loss to wheat and corn in this country, though instances of serious attack are recorded frequently upon other grains. Beans, chickpeas, and cowpeas usually are not attacked, though if held in storage for considerable periods the Angoumois grain moth has been known to cause much damage, particularly in seeds already slightly injured by handling or by bean-weevil attack. Rice handled under commercial conditions is very seldom affected.

LOSSES

It is difficult to estimate the amount of loss caused grain growers, dealers, and millers by the Angoumois grain moth. Throughout the extreme South it is rated as a pest second only to the rice or "black" weevil.[3]

Throughout the wheat belt of southeastern Pennsylvania, New Jersey, Delaware, and Virginia, it is the worst pest of ripening wheat and wheat in storage. Many crops have suffered a loss of 10 to 60 per cent. Millers have not infrequently refused to purchase badly damaged grains because they contained so many dead insects and insect excrement. Flour made of badly infested seeds is not palatable. The actual weighing of 1,000 kernels of sound wheat and a like number of infested kernels showed a loss by weight of 56.2 per cent as a result of the development of a single moth in each of the infested kernels. (Fig. 9.)

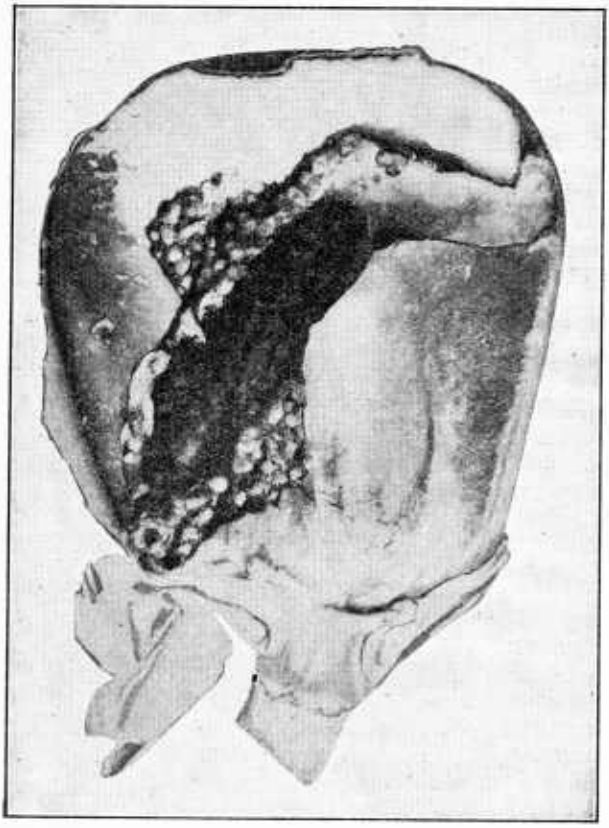

FIGURE 5.—Cross section of one of the kernels of corn in Figure 3, enlarged to show the cavity made by the larva of the Angoumois grain moth, the silken chamber formed by the larva, before transforming to the pupa. The large brown or blackish appearing object is the pupa from which the moth will emerge and crawl along the silken channel in escaping from the seed

Corn does not lose so great a percentage of its weight. The weights of an equal number of infested and perfect kernels representing seven varieties of soft, dent, and flint corn showed that where but one moth had developed in each infested kernel the infestation had caused a loss in weight amounting to 13.1, 13.2, 15.5, 17.3, 19.7, 23.5, and 24 per cent, respectively. The loss in weight varies with the ratio between the size of the kernel and the amount eaten by the individual insect in reaching its maturity.

[3] *Calandra oryza* L.

MATURING GRAIN AND STORED GRAIN SUBJECT TO ATTACK

The Angoumois grain moth feeds both in dried grain in storage and in grains maturing in the field. In storage the pest breeds generation after generation as long as the food supply lasts. This may be several years in what are commonly believed to be "air-tight" containers. In agricultural districts, especially where the pest is breeding in storage in open bins or mows, the moth is driven by instinct to leave the warehouse, barn, or crib in varying numbers and fly to the near-by fields in search of maturing grains in which to lay eggs for the first summer generation in the field. Of course, many remain behind in the crib to multiply continuously throughout the year.

INFESTATION OF CORN

Corn has an advantage over the smaller grains in that most of the kernels are covered during growth by the husk covering. It has

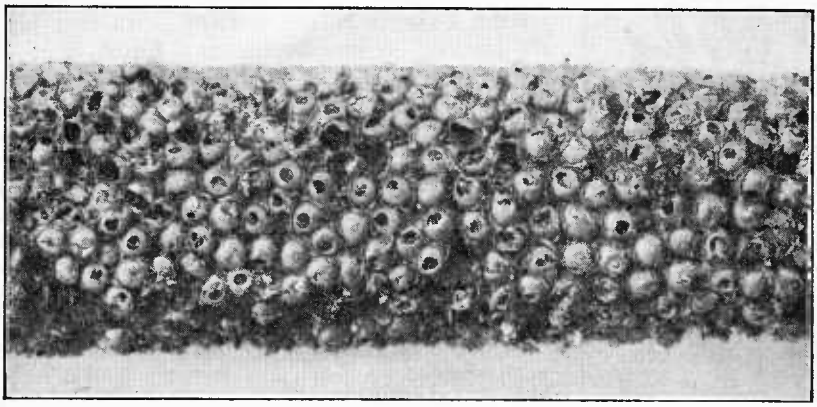

FIGURE 6.—A spike of sorghum with each seed showing the emergence hole of the Angoumois grain moth. The moth completely ruins so small a seed as this

already been pointed out that destruction by the Angoumois grain moth takes place in the larval stage. The parent which flies from grain in storage to the field to start the first generation in maturing grain can not eat into the shuck covering. Hence corn protected by a well-developed, uninjured shuck covering is never affected. But where the shuck is either loosely developed at the tip or damaged by smut, corn ear worm,[4] or other insects, the moth can easily reach the kernels and lay her eggs upon them, thus starting an infestation.

These relatively few cases of infestation in the field serve as centers of infestation from which following generations of moths maturing in standing corn or corn shocked in the field, or corn that has been placed in the crib, will spread in large numbers and bring about a general infestation of the entire lot of corn in storage. There is practically no infestation of corn in the field except in the more southern States. As far north as Maryland instances of field infestation are very rare, and there is little danger of infestation where

[4] *Heliothis obsoleta* Fab.

corn is stored in ordinary slatted cribs until the coming of warm weather of the following summer. But in the Gulf Coast States, especially when the corn is growing on poor land, where shuck development is poorest, the infestation of maturing ears may be very general and result in heavy losses in storage.

Figures 1 to 5 and 10 illustrate the manner in which corn is injured. The moth lays her eggs usually between the kernels on the cob. On shelled corn the eggs may be laid anywhere. The newly hatched larva usually crawls to the germ end of the seed, bores in through the seed coat, which is there more tender, and thus finds itself in the softest part of the kernel. From the illustrations it will be seen that the larva usually eats out and destroys the embryo or germ, and then bores its way outward into the harder part of the seed. (Figs. 1 and 4.) More often the emergence hole is found on the outer portion of the kernel, though this is not always so. Ordinarily development occurs entirely within a single kernel, yet the larva may begin its feeding in one kernel and finish it in the adjoining one. In some varieties of corn many larvae form their emergence holes at the base of the kernel, so that the moth in attempting to escape from the kernel finds itself wedged in by the surrounding kernels and forced to starve, since only the larva of the moth can feed on grain. Although many moths in an ear may lose their lives in this way, yet enough emerge normally to cause heavy infestations.

FIGURE 7.—A head of beardless barley showing the emergence holes of the Angoumois grain moth. Remember that unthreshed wheat, rye, oats, or barley are not at all protected from the moth

While the young larva can not eat through corn shucks to reach the kernels, those hatching from eggs laid through breaks in the shuck covering may be so numerous, particularly in storage, that they spread to and enter nearly all the kernels on an ear, even those kernels well covered by the shuck. Although the newly hatched larva can not eat through the shuck to the kernel, the mature larva, which is much stronger, may bore its way out from the kernel through the shuck covering to the exterior. Instances have been found where the larva of the Angoumois grain moth has eaten through eight and nine thicknesses of shuck covering, though ordinarily escape is not effected where there are this number of thicknesses. Infestation of kernels at the tip of an ear may take place if the silk has been eaten out, thus leaving a channel down which either the moth or the newly hatched larva can crawl. While the infestations that occur through eaten-out silk channels and through breaks in the shuck covering are not in themselves usually of importance from the standpoint of grain actually destroyed, they are of immense importance as "leaven"

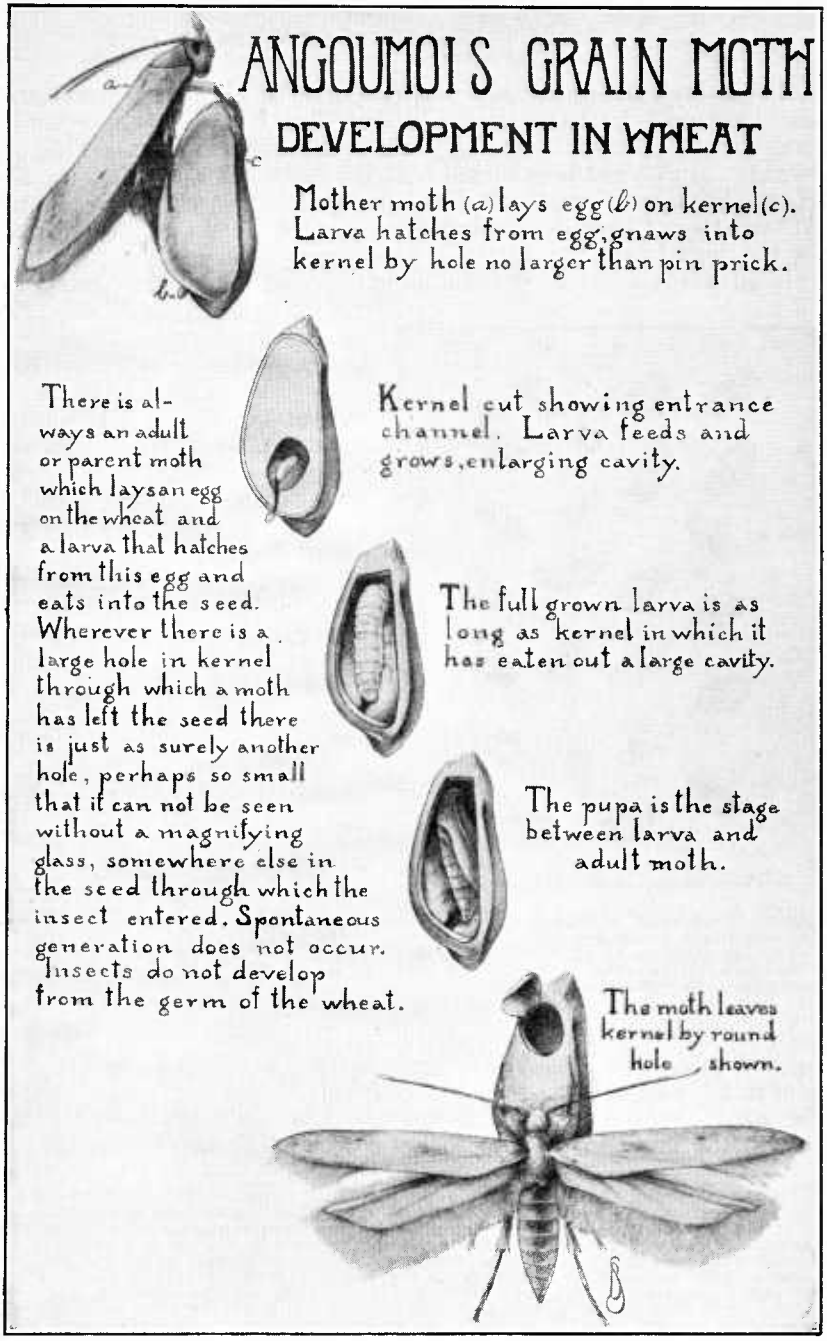

FIGURE 8.—Development of Angoumois grain moth on wheat. Life cycle

for the subsequent infestation of entire crops held carelessly in storage.[5]

FIELD INFESTATION OF WHEAT

It has been stated already that the adult of the first generation of the Angoumois grain moth instinctively flies from the crib or storage house to the near-by fields of grain as the crop is approaching maturity. It also has been stated that the moth can not infest the corn if the shuck covering is well developed and uninjured. The planting of varieties of corn developing a long, tight shuck, as recommended by the department,[6] will greatly lessen moth injury in the field. But this advantage which corn has is not shared by wheat, barley, and similar small grains. The female moth upon flying from bin to field may lay from 20 to 30 eggs upon the head of wheat chosen for attack. The larvae hatching from these eggs scatter over the head, only one entering each kernel. The thin membranes covering the kernel are no hindrance to the entrance of the larvae. This starting of infestation in the field may take place, as King[7] has proved beyond doubt, even while wheat is "in the milk." Infestations of growing wheat are most heavy nearest places where infested wheat has been stored throughout the winter and spring.

FIGURE 9.—Kernels of wheat showing the small round emergence holes that prove that an Angoumois grain moth has developed in the seed, thus reducing its weight somewhat over 50 per cent

EARLY FIELD INFESTATIONS AND DELAYED HARVESTING INCREASE OPPORTUNITY FOR DAMAGE

There is a direct relationship overlooked by many wheat growers between early field infestation, delayed harvesting, and damage caused by the Angoumois grain moth. In southern New Jersey, Maryland, and southeastern Pennsylvania the first moths appear in the wheat fields about the time the wheat is "in the milk." In other words, the moth may begin to lay eggs in the wheat heads at any

[5] If the Angoumois grain moth were the only pest farmers had to contend with, it would be better to keep corn in storage with the shucks on, as good shuck cover is a great aid to conservation of corn against this pest. Unfortunately in sections where the moth is a serious pest of corn, the corn is also attacked by the rice or "black" weevil, against which shucks are of far less protection. If corn is shucked at harvest and fumigated at once, so practical experience on the southern farms is proving, losses due to any insect are greatly reduced or entirely prevented during the time of storage.

[6] For further discussion of long tight shuck, see KYLE, C. H. HOW TO REDUCE WEEVIL WASTE IN SOUTHERN CORN, U. S. Dept. Agr. Farmers' Bul. 915, 8 p., illus. 1918.

[7] KING, J. L. THE ANGOUMOIS GRAIN MOTH. Pa. Dept. Agr., Bur. Plant Industry Circular No. 1, 14 p., 2 figs. 1920.

time after the kernels are well set.[8] As each moth may live from 10 to 38 days, during which she flies about the field laying eggs in batches of 1 to 20 or more until she has laid about 150 eggs, it will be understood that a field of grain may have many heads infested by the early summer flight of moths from near-by cribs or granaries. Ordinarily these first early summer infestations are very slight and cause no appreciable loss if the crop is handled correctly.

Field infestation at the time wheat is ready for harvest has been observed to amount to from 0.26 to 2.06 per cent of the kernels. This is equal to a population of 28,500 to 225,000 moths per acre.

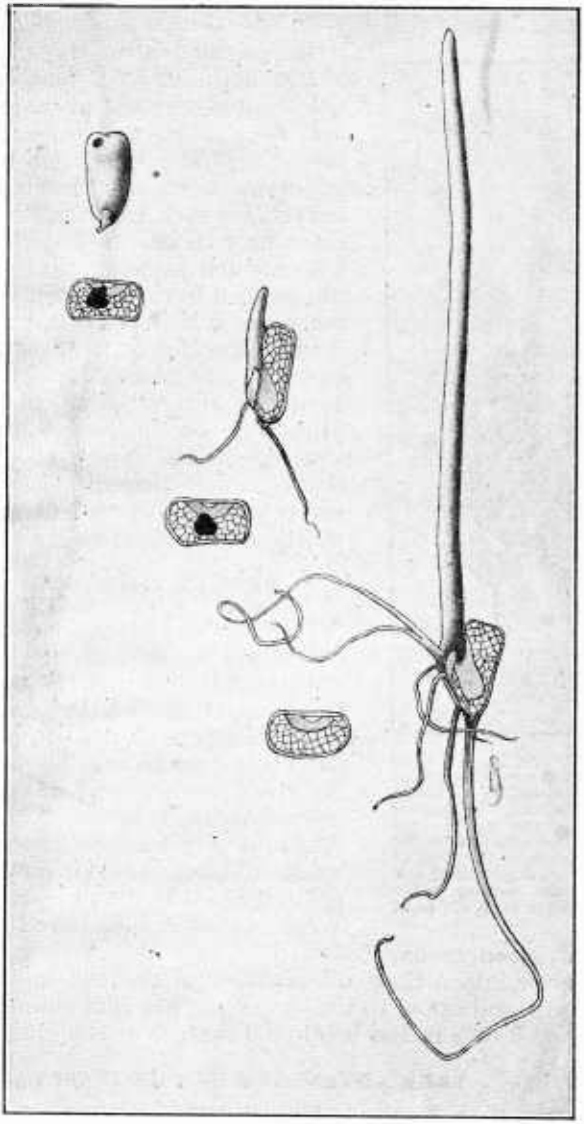

FIGURE 10.—Three kernels of corn, the lowest one free from attack and sprouting normally. The larva of the Angoumois grain moth has completely destroyed the germ of the upper kernel and it has failed to sprout. The germ of the middle kernel has been affected only slightly by the developing moth, yet notice how small its shoot is as compared with that of the normal seed; it will die or produce a sickly plant. Do not plant seed infested with the Angoumois grain moth

SECOND AND THIRD GENERATIONS IN FIELD SPREAD LIKE WILDFIRE

The first generation of moths in the maturing heads of wheat, as just stated, usually is not a large one. But for each female moth of the first generation that reached the field in late May and June there may be 150 moths of the second generation maturing in middle July and August. Ordinarily the

[8] SIMMONS, P., and ELLINGTON, G. W. DISPERSION OF THE ANGOUMOIS GRAIN MOTH TO WHEAT FIELDS. Jour. Agr. Research, Vol. 34, pp. 459–471, 1927.

moths of the second generation begin to appear soon after the grain is ready to cut, though a few may mature before the grain is ripened. The moths for the third generation appear during late August and during September. Granting that the sexes are evenly divided, and each female will lay on an average 150 eggs, for each female moth flying to the field in May or June there are about 11,250 moths, or 5,625 female moths ready to start the third generation of infestation in late August and September, and these moths are capable of laying 843,750 eggs. As only one Angoumois grain moth usually develops in a single wheat kernel, for each infested kernel in May and June there may be in late August and September 843,750 infested kernels. And if the grain is stored unthreshed in the barn where the moths can easily reach the kernels, or is left unthreshed in the field during warm weather, infestation may increase to 63,281,250 kernels in October for each infested kernel in May or June, provided all eggs hatch, all larvae reach maturity, and all females lay an average of 150 eggs. If this infestation which occurs before threshing could be eliminated this severe and widespread damage now often caused by the moth would be a thing of the past.

FIGURE 11.—A head of maturing wheat showing three adult Angoumois grain moths that have flown from the crib to the field of ripening grain and are seeking to lay eggs upon the head

PROMPT THRESHING MEANS SAVING

It is known that grain standing in the field uncut, grain stacked in the field, or mowed away unthreshed in barns, is not protected from so small an insect as the Angoumois grain moth. The moths are so small that they can crawl into unthreshed grain and lay their eggs. They prefer the more exposed outer heads but they can infest the inside heads. It is also known that the Angoumois grain moth while very small is too weak to force its way down into wheat or any grain when it is stored in bulk or large quantities. When stored in bins only the upper 1 or 2 inches of grain become infested. Since the moth is too weak to burrow down into a mass of wheat, it is also too weak to push the kernels aside and crawl to the top of the bin if it comes out of a kernel more than 2 or 3 inches below the surface of the grain.

TAKE ADVANTAGE OF THE INSECT'S WEAKNESS

Farmers can turn this weakness to their advantage. If wheat is cut as soon as ripe, threshed as soon as dry, and placed at once in storage in deep bins where only a relatively small surface of wheat is exposed, the Angoumois grain moth will not ordinarily cause trouble. The relatively small quantity of wheat that is infested by the time it is ripe and can be threshed is not great enough to cause heating in the bins as a result of moth infestation. The moths that develop in the kernels well below the top of the bin die without reproducing because they are too weak to extricate themselves. The same

result is obtained when the wheat is placed in closely woven sacks that are well closed. The early harvesting and proper storing of wheat nips in the bud the first early infestations that occur in the field, without cost or material loss to the grower.

DELAYED THRESHING RUINS MANY CROPS

The greatest argument against early threshing of wheat is the difficulty of getting a threshing machine just when it is needed. Where a community depends upon a traveling threshing machine, farmers must wait their turn. A period of wet weather after cutting may prevent threshing, though it does not prevent the moth from multiplying. Wet weather can not be overcome, but farmers can combine more effectively in arranging for the prompt threshing of their wheat. The amount of wheat saved by early threshing during occasional bad "fly weevil" years will often pay many times over for the investment required to own a threshing machine. The farmer can choose between prompt harvesting, early threshing, proper storage, and little or no loss, and delayed harvesting, late threshing, and great loss. It will pay him to provide against loss.

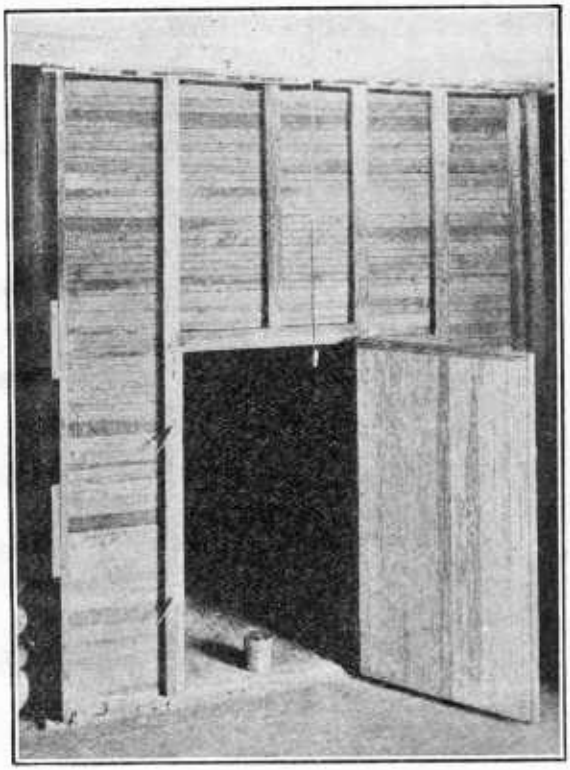

FIGURE 12.—Front view of a specially constructed fumigating room used for killing insects in corn, wheat, and other substances. It is made of double thicknesses of matched boards with building paper between. Such a room is valuable for fumigating sacked grain with carbon disulphide or other effective fumigant

REMEDIAL MEASURES

The most satisfactory method of controlling the Angoumois grain moth attacking almost any crop, but especially wheat, is, as just stated, prompt harvesting and storing under conditions unfavorable to the moth attack. (Figs. 12 to 16.) The great losses that are reported throughout wheat areas affected by the pest are the result of delayed harvesting, threshing, and storing. The storing of wheat unthreshed in barns or stacking it unthreshed in the field increases

the loss. Prompt harvesting, threshing, and storing in deep, tight bins, or in tight sacks, is effective. Wheat should never be left spread in thin layers on barn floors except when too wet to store. Such a practice makes it easy for the moth to lay eggs on kernels.

DRYNESS

It is stated that where practicable to store grain under dry conditions, the amount of damage done by the Angoumois grain moth will be reduced greatly. If the moisture of the grain can be reduced to 13 per cent or below, infestation will make little or no headway.

FUMIGATION

If grain is found badly infested with the Angoumois grain moth, it should be fanned and screened. Such treatment will remove about

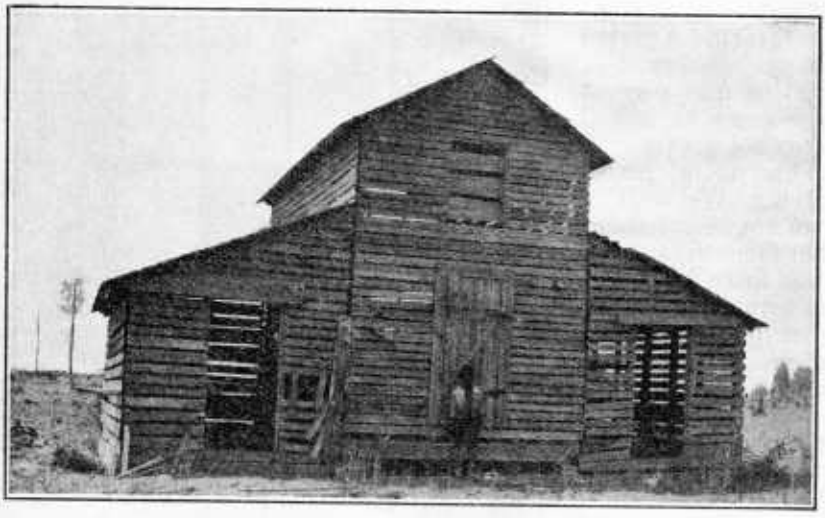

FIGURE 13.—A slatted corncrib. Such corncribs are no protection from insects to corn stored in them in the extreme South. Corn stored in slatted cribs from Maryland northward is safe from Angoumois grain moth attack at least until the summer following harvest, as the cold of winter is usually sufficient to prevent moths from surviving the winter in slatted cribs

half of the infested kernels of wheat, but will not remove infested kernels of corn. Remember fanning only removes adult moths, débris, and light kernels. To kill the moth in the remaining crop the seeds must be fumigated or heated. The best fumigants are hydrocyanic-acid gas, carbon disulphide, and the ethylene dichloride-carbon tetrachloride mixture. Hydrocyanic-acid gas is lighter than air, very deadly to man as well as insects, and is used in killing the moths in grain stored unthreshed. It is not recommended for the treatment of threshed grain in bulk unless the fumigation is effected through the addition of calcium cyanide to the stream of wheat as the grain enters the bin. This fumigation of bulk grain with calcium cyanide is conducted only at elevators where special equipment for the application is available. Farmers with ordinary bins should not attempt to use calcium cyanide until this method of control has been developed further, because of certain risks connected with its use.

FIGURE 14.—Corncrib belonging to farmer in Georgia. This was originally a slatted crib, but the weevils were so destructive that he covered it with building paper and a layer of tongue-and-groove boarding, made his floor tight, and fumigated with carbon disulphide. He no longer fears weevils. Anyone can make his crib tight by following the advice of the county agent

FIGURE 15.—An old-style barn with lean-to sheds. The owner could not store corn or wheat and keep it free from weevils. At the advice of the county agent he sealed the barn on the inside with tongue-and-groove boarding, and filled the space between the rough outer boards and sealing with packed sawdust. He then fumigated with carbon disulphide and killed all weevils. Use your ingenuity to tighten your old crib or build a new one, according to the advice of your county agent

Threshed grain in bulk should be fumigated with carbon disulphide or the ethylene dichloride-carbon tetrachloride mixture. These gases, which are heavier than air, are used for the destruction of moths in grain stored in bins and tight rooms. They will not injure the seed for planting if the seeds are thoroughly dried at the time they are fumigated.

At present carbon disulphide is a standard fumigant for farm use, and is safely and successfully used by thousands of farmers. Precautions, however, are necessary in its use. *Keep all lighted cigars, matches, lanterns, or fire in any form away from the bins or buildings during the fumigation, as the gas is explosive and inflammable in the presence of the smallest spark.* Fumigations are not very effective at temperatures lower than 60° F. Carbon disulphide should be used at the rate of from 4 to 10 pounds for each 1,000 cubic feet of bin space to be fumigated, according to the tightness of the bin. It pays to make the bin tight and save on the cost of the fumigant. Carbon disulphide may be poured directly upon the seeds, or better still upon gunny sacks spread over the top of the grain. Never pour the fumigant on the seeds at one spot only. The liquid will not injure the seeds for feeding or milling if used as directed, but if poured in one spot the seeds there may become so wet that their milling properties may be affected. The liquid quickly evaporates at temperatures over 60° F., forming a gas that sinks into the grain and kills the insects.

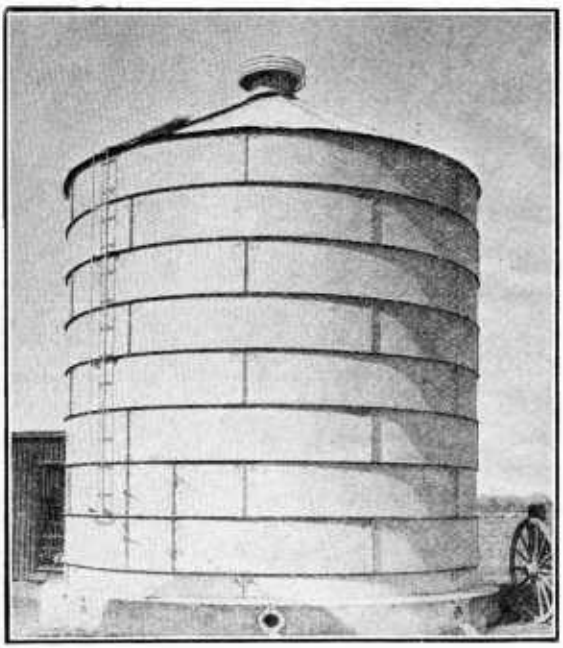

FIGURE 16.—A modern galvanized-iron corncrib planned and erected by a progressive dairyman of Louisiana. Soft white dent corn has been kept in this crib in perfect condition for over a year. Weevils breed in such cribs as fast as in any, but are easily killed by fumigation with carbon disulphide. (Photograph by Jones)

Information regarding the fumigating of grain is given more in detail in Farmers' Bulletins Nos. 799 and 1483, which may be had free by writing to the Department of Agriculture, Washington, D. C.

HEAT

The average farmer is not equipped to use heat in controlling the Angoumois grain moth. Millers and grain dealers who have dryers

can heat wheat to 120° or 125° F. If grain is heated to this temperature for several hours all insects in it will be killed. Heating to from 120° to 125° will not injure its germinating power.

PARASITES

A parasite [9] and a mite [10] often come to the farmers' aid and kill large numbers of the moth. Ordinarily, however, they do not become of service until the moth has caused much damage. It is not practical at present to depend upon parasites to reduce losses in field or storage.

COMMUNITY EFFORT IN INSECT SANITATION

The Angoumois grain moth has never been fought vigorously by farmers. Certain few men protect their crops and reap a saving. Many farmers wake up too late and find their crops already badly affected. Lack of labor and threshing machines forces some farmers to do the best they can without them. But all farmers can support a campaign in their own communities to kill out the Angoumois grain moth. Experiments have proved that the moth in the region of winter wheat can not live through the winter in the grain sown in the fall. Hence farmers can center their attack upon the pest in the cribs and granaries. Farther south the pest may live through the winter in grain left in the field. The county agents representing both State and Federal departments of agriculture should interest farmers in their counties in campaigns along the lines of insect sanitation. No pest can be more effectively controlled than the Angoumois grain moth. Success in this mode of attack in the northern range of the habitat of the pest depends upon the thoroughness with which farmers combine to treat infested grain in storage, and in cleaning out their cribs in the spring. In the more southern States success depends upon removing the crop thoroughly from the field as well as attending to disinfection in the crib and cleanliness of the crib after the crop has been removed from it. L. O. Howard first recommended control of the Angoumois grain moth through community effort over 30 years ago.

If county agents in sections where the moth is injurious can unite farmers in a campaign of control they will save the farmers of their counties grain worth many times the salaries paid them. Intelligent insect sanitation pays handsome returns.

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[9] *Pteromalus gelechiae* Webster.

[10] *Pediculoides ventricosus* Newport.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

June 26, 1929

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